Migrating from IPv4 to IPv6: planning an effective IPv6 transition

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Why a transition to IPv6?

• The IPv4 addresses are running out
• The Internet routing system is getting overloaded
• IPv6 provides new features
  – virtually unlimited addressing space
  – native support for mobility, security, multicast, etc.
  – plug & play
• The cost of a “non-transition”
  – the use of private addresses and NATs breaks end-to-end transparency (failure of some applications & loss of flexibility )
  – enhancing IPv4 to make it IPv6-like is costly
Availability of IPv4 addresses

• Theoretical upper bound: $2^{32} \sim 4$ billions
• Practical upper bound: $\sim 200$ millions
  – the hierarchical nature of the Internet limits the assignment efficiency (rfc1715)
• Assigned IPv4 addresses
  – $\sim 72$ millions (January 2000)
  – these are just the addresses registered in the DNS system (i.e. a lower bound)
  – the growth is exponential
• When will we reach the upper bound of 200 million hosts in the Internet?
Internet growth forecasts

Source: Internet Software Consortium (http://www.isc.org)
Backbone routing overload

Growth rate: ~15000 routes/year

Source: http://telstra.net/ops/bgptable.html
When should we start?

• Certainly not later then 2003
  – sometime between 2001 and 2003 getting a bunch of global IPv4 addresses might become really difficult

• But it is much better to start sooner
  – more time to plan a smooth transition
  – more time to gain the necessary IPv6 expertise
  – just setting up an early IPv6 service is cheap
  – several ISPs and user communities have already begun
IPv6 deployment issues

• IPv4 and IPv6 do not interoperate
  – IPv4 applications do not work with IPv6
  – IPv4 nodes can not communicate with IPv6 nodes

• The applications have to be modified
  – a lot of work still has to be done......

• It is likely that IPv4 and IPv6 will coexist for a long period of time
  – how to enable communications among IPv6 islands isolated in the IPv4 world?
  – how to enable communications between the existing IPv4 world and the new IPv6 world?
Basic transition mechanisms

• Dual IP Stack
  – provision of complete support for both IPv4 and IPv6 in hosts and routers

  ![Diagram of dual-stack node]

• IPv6 over IPv4 tunneling
  – encapsulation of IPv6 packets within IPv4 headers to carry them over an IPv4 network (e.g. Internet)
  – two types of tunneling: configured and automatic
Configured tunneling

IPv6 island

IPv4 network

IPv6 island

IPv6 host IPv6 host IPv6 host


Tunnel

User Data

TCP Header

IPv6 Header

User Data

TCP Header

IPv6 Header

User Data

TCP Header

IPv6 Header

Encapsulate

Decapsulate

Src = R1.IPv4

Dst = R2.IPv4
Automatic tunneling

IPv4 site

R1
IPv4 Router

IPv4 network

Tunnel

R2
IPv4 Router

IPv4 site

dual-stack host

dual-stack host

User Data
TCP Header
IPv6 Header
IPv4 Header

Src = S.IPv4
Dst = D.IPv4

IPv4 compatible addresses

Automatic Derivation

Src = ::S.IPv4
Dst = ::D.IPv4

Encapsulate

Decapsulate

CSELT
The need for other tools

• Issues with simple dual-stack
  – it does not reduce the demand for globally routable IPv4 addresses
  – it increases network complexity due to the need for a double (IPv4/IPv6) routing infrastructure

• Issues with simple tunneling
  – configured tunneling requires heavy manual configuration and therefore does not scale well
  – automatic tunneling is not the solution because it can be used only between individual hosts
Other dual-stack approaches

• **DSTM (Dual Stack Transition Mechanism)**
  – deployment of dual-stack nodes with dynamically assigned IPv4 addresses
  – IPv4 over IPv6 tunneling to avoid the need for a dual-stack routing infrastructure

• **Application Level Gateways (ALG)**
  – the client is IPv6-only and the communication with the IPv4 world goes through a dual-stack proxy
A dual-stack alternative

- **NAT-PT (NAT - Protocol Translator)**
  - the customer site is an IPv6-only network
  - the communication with the IPv4 world relays on a NAT box that translates between IPv4 and IPv6
Issues with NAT-PT

- More or less the same as IPv4 NATs
  - some applications may not work (need for ALGs)
  - IPsec, Mobile IP, etc. fail (no e2e transparency)
  - performance degradation
  - single point of failure
  - need for strict coordination with DNS for automatic translation state initialization

- But
  - unlike IPv4 NATs, NAT-PTs are just a temporary solution
  - after the transition has been completed the NAT-PT box may be removed
Tunneling enhancements

• Tunnel Broker
  – automatic tunnel and DNS setup assisted by a tunnel broker server operated by the IPv6 ISP

• 6over4
  – IPv6 hosts in an IPv4 site communicate through automatic IPv6 over IPv4 encapsulation
  – a virtual link is created relaying on IPv4 multicast to enable IPv6 Neighbor Discovery over IPv4

• 6to4
  – interconnection of isolated IPv6 domains in an IPv4 world (e.g. Internet)
  – the egress router of the IPv6 domain automatically creates a tunnel to the other domain
The tunnel broker service at CSELT

1. The client provides minimal configuration information

2. Tunnel Broker configures client, DNS and the selected Tunnel Server

3. The tunnel is now up and working

Wide area IPv6 network (6bone, 6REN, etc.)

Service available at: https://carmen.cselt.it/ipv6tb
6over4 operation

IPv4 Multicast Network

6over4
Cloud

Encapsulated

R4/6
6over4

Dual-Stack

IPv4 end-point and router discovery via ND
- the whole IPv4 network becomes a virtual IPv6 link
- IPv6 multicast mapped over organization-local IPv4 multicast

Native Cloud
6to4 operation

- IPv6 Addressing
  - any isolated IPv6 domain can autonomously build its own globally unique IPv6 prefix
  - the globally unique IPv4 address of the domain border router is used for this purpose

![Diagram of 6to4 operation](image)

<table>
<thead>
<tr>
<th>16</th>
<th>32</th>
<th>16</th>
<th>64 bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>6to4 TLA</td>
<td>IPv4 address</td>
<td>SLA ID</td>
<td>Interface ID</td>
</tr>
</tbody>
</table>

Well known 0x2002

Example

IPv4 address = 163.162.1.1
6to4 prefix = 2002:A3A2:0101::/48
6to4 operation (cont.)

• Communication among 6to4 sites
  – the egress router automatically creates a tunnel to the destination domain
  – the IPv4 endpoint is extracted from the destination IPv6 prefix
  – only the egress router has to be 6to4 capable
6to4 operation (cont.)

- Communication with the native IPv6 world
  - based on 6to4 relays
  - a 6to4 router must be able to locate at least one 6to4 relay (e.g. manual conf.)
Summary

• How to enable communications among IPv6 islands isolated in the IPv4 world?
  – simple tunneling (configured or automatic)
  – Tunnel Broker
  – 6over4
  – 6to4

• How to enable communications between the existing IPv4 world and the new IPv6 world?
  – simple dual-stack
  – Application Level Gateways (ALG)
  – DSTM
  – NAT-PT
Availability of IPv6 applications

- A lot of work still has to be done
  - just a few IPv6 applications are available to time (e.g. ftp, telnet, ping, some WWW browsers)
- BIS (Bump In the Stack) may be of help
  - to use of IPv4 applications over an IPv6 network
  - it is like NAT-PT implemented within the host
Transitions scenarios

- **Company**
  - new organization
  - existing organization with lots of IPv4 addresses
  - existing organization with private IPv4 addresses and NATs
- **ISP**
  - backbone ISP
  - small/medium ISP
New organization

- **Network technology:**
  - deploying an IPv6-only network is future proof

- **Communication with the IPv4 world**
  - at least one global IPv4 address
  - NAT-PT or dual-stack ALG (e.g. WWW proxy)

- **Communication with other IPv6 domains**
  - IPv4-only ISP: configured tunneling or 6to4
  - dual-stack ISP: relay on the upstream IPv6 service

- **DNS**
  - a dual-stack DNS is required if the upstream ISP does not provide native IPv6 DNS
New organization (cont.)

- **Applications**
  - at least all the basic Intranet/Internet services (e.g. WWW, e-mail) must be provided over IPv6
  - BIS may be used to support IPv4-only applications
Existing organization

• Network technology
  – migration to dual-stack anywhere with configured tunneling or 6over4 during the transition

• Communication with the IPv4 world
  – IPv4 end-to-end (if lots of addresses are available)
  – or use the existing proxy or NAT box

• Communication with other IPv6 domains
  – IPv4-only ISP: configured tunneling or 6to4
  – dual-stack ISP: relay on the upstream IPv6 service

• DNS
  – AAAA Records must be supported
Backbone ISP

- **IPv6 equipment**
  - deployment of dedicated IPv6 routers and servers
- **Addressing**
  - apply for a TLA prefix (RIPE, ARIN or APNIC)
- **IPv6 connectivity in the backbone**
  - initially configured tunneling over the existing IPv4 infrastructure should be enough
  - migration to native links as the IPv6 traffic grows
- **IPv6 connectivity with other ISPs**
  - setup of IPv6 peerings with other big ISPs
  - the IPv6 peering policies should be similar to those in place for IPv4
Backbone ISP (cont.)

- **IPv6 connectivity to customers**
  - configured tunneling or native connections
  - provision of a 6to4 relay service to reach isolated 6to4 clouds
  - the Tunnel Broker approach may be suitable for residential customers or small networks
Transition steps

• **Laboratory experiments**
  - network services
  - applications

• **Geographical experiments (6bone)**
  - DNS
  - IPv6 addressing
  - BGP4+ routing
The transition to IPv6 has already begun.....
For further information....

- IETF ipng working group  
- IETF ngtrans working group  
- 6bone  
  - http://www.6bone.net
- IPv6 Forum  
  - http://www.ipv6forum.com
- CSELT Official IPv6 Site  
  - http://carmen.cselt.it/ipv6 (IPv4)  
  - http://carmen.ipv6.cselt.it/ipv6 (IPv4 & IPv6)